(P=0.04). We did not recognize a clear tendency in T2 relaxation time of cartilage in proximal top of the femoral head regarding OA change. The mean T2 relaxation time of the caritilage of the femoral head adjacent to acetabular labrum was extended in conjunction with degenerative change of acetabular labrum. This correlation was observed in prearthrosis joints which demonstratede no or minor OA change in plain X-ray (P<0.05). No significant relationship was observed between T2 relaxation time and age, body weight, CE angle or state of the contra-lateral hip joint.

Conclusions: T2 mapping techniques use T2 relaxation time as an indirect indicator of structural change within articular cartilage due to the alteration in interaction between water molecules and the collagen fiber network with progressive cartilage degeneration. This study demonstrated the clinical feasibility of T2 mapping using 1.5T MRI, which is widely used in clinic, to evaluate hip joints with acetabular dysplasia. In addition, the T2 relaxation time of cartilage was extended in conjunction with the degenerative change of acetabular labrum. The results suggest that acetabular labrum degeneration may play a important role in the pathology of OA in hip joints at an early stage.

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THREE-DIMENSIONAL DISTRIBUTION OF HEALTHY KNEE CARTILAGE T2 MAPPING IN VIVO

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Purpose: Some studies demonstrated potential of T2 mapping for assessing cartilage degeneration, but they were restricted to evaluation of limited area in the whole anatomical configuration, due to availability of few imaging planes at the femoro-tibial joints. Hence, there may be undetected, abnormal cartilage lesions which were located out of the imaging section and was undetected by those imaging techniques. The three-dimensional (3D) distribution of the articular cartilage thickness in the knee joint has been studied quantitatively using MR imaging in conjunction with computational processing techniques, and no studies assessed T2 mapping of articular cartilage in 3D knee models. The purpose of this study is to assess 3D-T2 mapping and thickness of femoral cartilage of healthy knee joint in vivo.

Methods: All participants provided informed consent to participate in the study, which was approved by the Institutional Review Board. Fourteen healthy subjects (24-38 years old, 7 male and 7 female, 7 left and 7 right) with no knee pain and no previous history of knee injury participated in this study. Each subjects' knee was imaged using a fast image employing steady-state acquisition cycled phases (Fiesta-C) sequence and T2 maps at 3.0T MR imaging system in the sagittal direction with the subject lying supine. T2 maps were generated using a monoexponential fit from 2D multi-spin echo sequences, in which consecutive imaging sections without interposition spaces were obtained by interleave acquisition techniques. In both sequences, the same sagittal imaging planes were obtained in each subject using identical axial localizing images. Cartilage region were manually traced in each Fiesta-C image in custom-made software, and used to construct 3D anatomic models of the femoral cartilage of the knee joint. 3D-T2 mapping of femoral cartilage was constructed using that 3D anatomic model of the femoral cartilage (Fig. 1). We assessed regional T2 mapping of femoral cartilage by dividing them into three regions of interest (ROIs), trochlea of the femor (TrF), medial femur (MF), and lateral femur (LF). TrF was used for aspects of the femoral cartilage located anterior to the intercondylar notch, and MF and LF for the medial and lateral aspects of femoral cartilage posterior to it. The ROIs of the cartilage of MF and LF were designated to be divided into an external and an internal subregion (eMF, iMF and eLF, iLF) (Fig. 2).

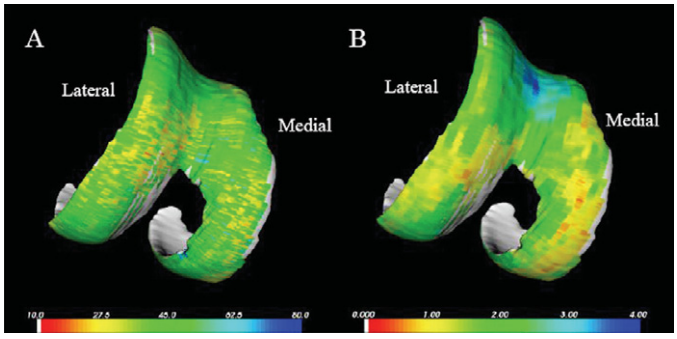

Figure 1. (A) 3D-T2 mapping of femoral cartilage. (B) 3D mapping of cartilage thickness.

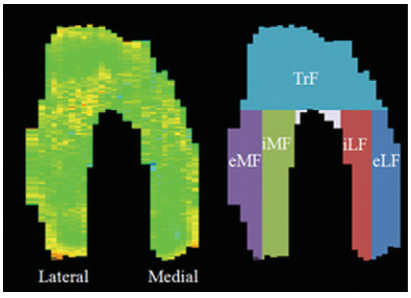

Figure 2. 2D-T2 map constructed from each sagittal T2 map and ROIs in the T2 map.

Results: By the overall inspection of 3D-T2 and 3D-thickness mappings, anterior and posterior portions on the medial and lateral femoral cartilages tended to show higher T2 values and lower thickness, as compared with intermediate portions (Fig. 1). The average T2 values of femoral cartilage were 39.6±3.5ms/38.3±2.9ms in the medial/lateral condyle, and the average thickness were 1.7±0.3mm/1.7±0.3mm in the medial/lateral condyle, respectively. Cartilage T2 values at eMF/iMF/eLF/iLF/TrF were 38.5±3.7ms/40.6±3.3ms/37.1±2.8/39.6±2.6ms/37.2±2.3ms,respectively. (Fig. 3a) There were no significant differences among ROIs. Cartilage thickness at eMF/iMF/eLF/iLF/TrF were 1.6±0.2mm/1.7±0.3mm/1.6±0.3mm/1.7±0.2mm/2.1±0.4mm, respectively. Cartilage thickness in TrF had significantly higher value, compared to other ROIs ($p < 0.05$).

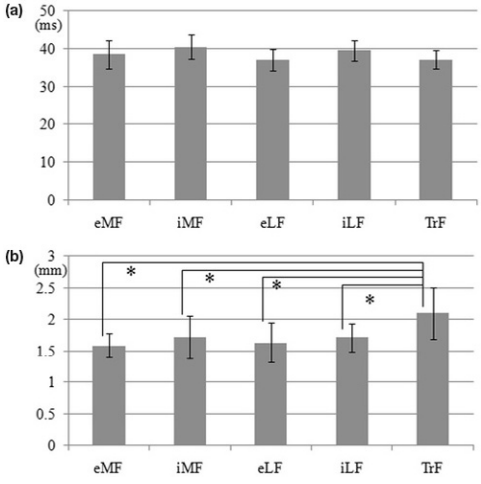

Figure 3. (a) The T2 values of ROIs (N=14). (b) The cartilage thickness of ROIs (N=14). *Significant difference among ROIs (P<0.05).

Conclusions: The present study is the first to reveal characteristic patterns of cartilage 3D-T2 mapping in normal knees in vivo. The present finding that enabled to assess quantitatively whole femoral cartilage of knee joint may aid in understanding the normal morphology and condition of the femoral cartilage, investigating which region of femoral cartilage tend to degenerate first and the mechanism of osteoarthritic involvement in the local area. This result may make it possible to evaluate cartilage degeneration without morphology change.

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THE RELATIONSHIP BETWEEN QUADRICEPS ARTHROGENOUS INHIBITION, PAIN, AND BONE MARROW LESIONS IN SUBJECTS WITH SYMPTOMATIC PATELLOFEMORAL OSTEOARTHRITIS

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Purpose: In patients with knee OA, quadriceps weakness is a common clinical feature which is considered to be an important determinant of

disability and is due, in part, to arthrogenous muscle inhibition (AMI). AMI has been tied to swelling of the joint and pain but not to specific innervated structures where pathology might lead to spinal level feedback and cause AMI. Bone marrow lesions (BMLs) visualised on magnetic resonance imaging (MRI) have been implicated in the genesis of pain in knee joint in previous cross sectional and longitudinal studies. Given the centrality of BMLs to OA pathology and their neural innervation, we hypothesised that subjects with patellofemoral joint (PFJ) OA and BMLs may also have AMI of the quadriceps. The aim of this study was to assess the correlation between the percentage of quadriceps AMI, knee pain scores and the number, size and signal intensity of BMLs in predominantly PFJ OA.

Methods: Subjects were included if they had a K-L score grade 2 or 3 in the PFJ and this was greater than K-L score for the tibiofemoral compartments, aged between 40 -70 years and had symptomatic PFOA. Their symptoms were reproduced with stair climbing, kneeling, prolonged sitting or squatting or they had lateral or medial patellar facet tenderness on palpation or a positive patellar compression test. Pain was present daily for the previous 3 months and above a score of 4 on a 0-10cm VAS for a nominated activity.

AMI data were collected using the twitch interpolation technique by an assessor blinded to the BML scores. The maximal single peak torque value with a 1Hz twitch interpolation and also the activation deficit (AD) levels at 100% MVC were calculated as a percentage figure from the ratio: AD= Interpolated twitch torque/Resting twitch torque (ITT/RTT) $\times$100.

BMLs were defined as poorly marginated areas of increased signal intensity in the normally hypointense fatty marrow on fat-suppressed spin-echo images and were graded in each region from 0 to 3 based on the extent of regional involvement; 0= none; 1<25% of the region; 2 =25-50% of the region; 3 $\geq$50% of the region. BMLs in the PFJ were graded in the anterior femur and patella in the medial and lateral PFJ compartment respectively. Scoring was performed by a musculoskeletal radiologist who was blinded to the AMI values.

Pain was assessed firstly by subjects marking a 10 cm VAS scale (0 = no pain and 10 = worst pain) based on the degree of knee pain they experienced in the previous 7 days using a nominated activity. Secondly, subjects completed the Knee Osteoarthritis Outcome Score (KOOS) pain subscale. Correlation analyses were carried out using a Spearman's rho.

Results: 14 subjects were studied (8 males, 6 females, mean age 54 years, range 43–66).Their average AMI was 31.4% (range 7–50.5%). Spearman's rho revealed a highly significant correlation between the amount of quadriceps AMI and the total area of BMLs (r=0.837, P<0.0001). There was also a significant correlation between AMI and the number of BMLs (r=0.69 P<0.006). There were no significant correlations between pain and AMI (VAS r= -0.505, KOOS r= -0.073) and between pain and the number of BMLs (VAS r= -0.281, KOOS r= -0.086).

Table 1. Matrix table of correlation co-efficients (Spearman's rho)

	Mean signal intensity	Area of BML	Number of BML	Pain VAS	Pain KOOS	AMI
Mean Signal intensity		0.143	0.208	-0.207	0.353	0.305
Area of BML	0.143		0.781 p<0.001	0.103	-0.340	0.837 p<0.0001
Number of BML	0.208	0.781 p<0.001		-0.806	-0.281	0.690 p=0.006
Pain VAS	-0.207	0.103	-0.806		0.646	-0.505
Pain KOOS	0.353	-0.340	-0.281	0.646 p=0.646		-0.073
AMI	0.305	0.837 p<0.0001	0.690 p=0.006	-0.50	-0.073	

Conclusions: Associations between quadriceps AMI and both the area and the number of BMLs in predominant PFJ OA have been found in this small sample. There were no significant correlations between knee pain and BMLs or AMI. These findings indicate that BMLs should be considered as a source of quadriceps AMI.

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EFFECT OF B0 MAGNETIC FIELD CHANGES ON QUANTITATIVE T1ρ RELAXATION MEASUREMENTS

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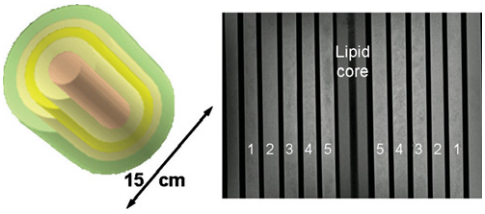
Purpose: Recent non-invasive MRI techniques have shown potential to serve as imaging biomarkers for assessing the state of cartilage health. T1ρ imaging is of particular interest because of its demonstrated sensitivity to proteoglycan changes both in vivo and in vitro without the need for introduction of an exogenous contrast agent. T1ρ relaxation times are affected by the low-frequency interactions between water and macromolecules such as proteoglycans. The lengthy RF pulses applied in T1ρ imaging may be sensitive to variations in the main (B0) field as well as the RF (B1) field, affecting quantification of T1ρ maps of tissues. Such variations may confound applications such as cartilage imaging where changes in T1ρ relaxation times are indicative of cartilage degradation in early stage OA.

This study assessed the effects of B0 field changes on calculated T1ρ relaxation times in a controlled phantom model.

Methods: A special phantom was designed to calibrate pulse sequence and artifact conditions across MR imaging sequences and platforms specifically for imaging protocols in the knee (Figure). The phantom was constructed of concentric Plexiglas rings separating compartments filled with 1% carrageenan + 1, 2, 3, 4, or 5% agarose gel doped respectively with 100,125,150,175,200μM $GdCl^{3-}$ to vary expected T1ρ and T1 relaxation times in the physiologic range for cartilage. The central core was filled with lipid material (lard). Phantom dimensions were set to fully load a standard transmit-receive extremity coil. T1ρ imaging was performed on a 3T Siemens TIM Trio scanner. The pulse sequence used a T1ρ preparation block with a $+90^\circ_x$ square pulse, 400 Hz spin lock pulse of four different durations (10, 20, 40, and 60 ms), a 90°_x tip-up, and a final crusher gradient, implemented to minimize B1 inhomogeneity effects. The magnetization preparation was applied to a FSE pulse sequence with TR/TE=3000/12 ms, echo train length of 7, and 256$\times$128 matrix over 4 slices. Sagittal images were acquired with a field of view of 175$\times$175 mm^2 and 4 mm slices, similar to in vivo protocols. After tuning with a 3D shim procedure, an initial control T1ρ set was acquired. Eight additional T1ρ data sets were acquired by adjusting the B0 frequency over a range of $\pm$63 Hz with all other parameters held equal. Mean T1ρ relaxation times were computed over 10$\times$40 pixel ROI regions within each ring of the gel phantom in each slice and compared to the control value for each gel and each frequency offset.

Results: Two B0 frequency offsets (+37 and +62 Hz) were excluded from the analysis due to severe artifacts that yielded highly inhomogeneous T1ρ values. T1ρ measurements at offset frequencies differed significantly from the control value ($p < 0.05$) for all but one of the gel samples and frequency offsets, with T1ρ relaxation times reduced by 5-10% depending on the magnitude of the frequency offset.



Conclusions: Results of this phantom study suggest that quantitative T1ρ relaxation measurements may be significantly influenced by variations in the B0 magnetic field, highlighting the need for careful tuning over the volume of interest to acquire accurate and reproducible results. Recent effort has been devoted to developing more B0 insensitive techniques for T1ρ magnetization preparation which may reduce these concerns. Nevertheless, the variability due to B0 field variations needs consideration when comparing derived T1ρ parameters across multiple studies and subjects, and deserves further study to assess its effects in vivo.

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REPRODUCIBLE MR MEASUREMENTS OF MENISCUS SUBLUXATION AND TIBIAL COVERAGE IN OSTEOARTHRITIS OF THE KNEE

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Purpose: Medial meniscus subluxation and tibial coverage are important findings in osteoarthritis of the knee, and simple reproducible approaches to quantify both findings could have scientific and clinical utility. We